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(71) Applicant(s)

GEC-Marconi Limited

(Incorporated in the United Kingdom)

The Grove, Warren Lane, STANMORE, Middlesex,
HA7 4LY, United Kingdom

(72) Inventor(s)

Roger Adrian Perrott

(74) Agent and/or Address for Service

G Cockayne

GEC Patent Department, Waterhouse Lane,
CHELMSFORD, Essex, CM1 2QX, United Kingdom

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(54) Signal processor system for a phased array antenna

(57) A signal processor system 10, 20 for the transmission or reception of orthogonal or non-orthogonal beams. In a transmission mode, a transmission signal from a transmitter 11 is routed through a diplexer 13 and divided into two equal sub-signals by a hybrid coupler 15. The phase of the two sub-signals are independently adjusted by phase shifters 16 and fed to the inputs of a beam transformer 17 as a first set of sub-signals for recombining to form aperture excitations required for a first beam. Resetting each phase shifter 16 to an alternative phase setting causes the recombination of a second set of sub-signals and results in the formation of aperture excitations required for a second beam.

The reception mode is essentially the inverse of the transmission mode with the exception of the diplexer 13 switching received signals to a receiver 12.

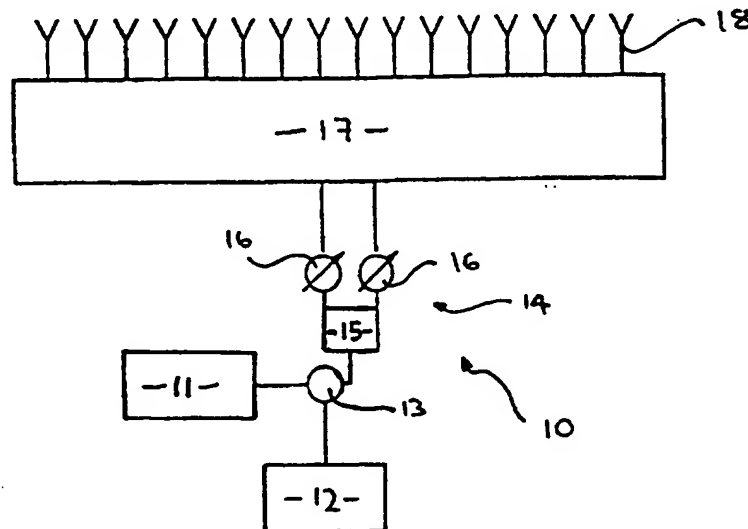


Fig. 1.

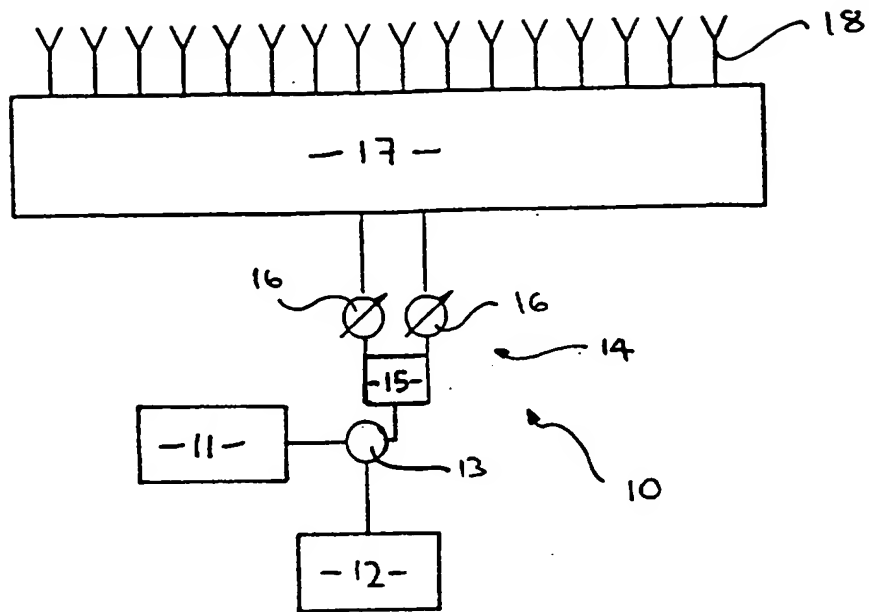


Fig. 1.

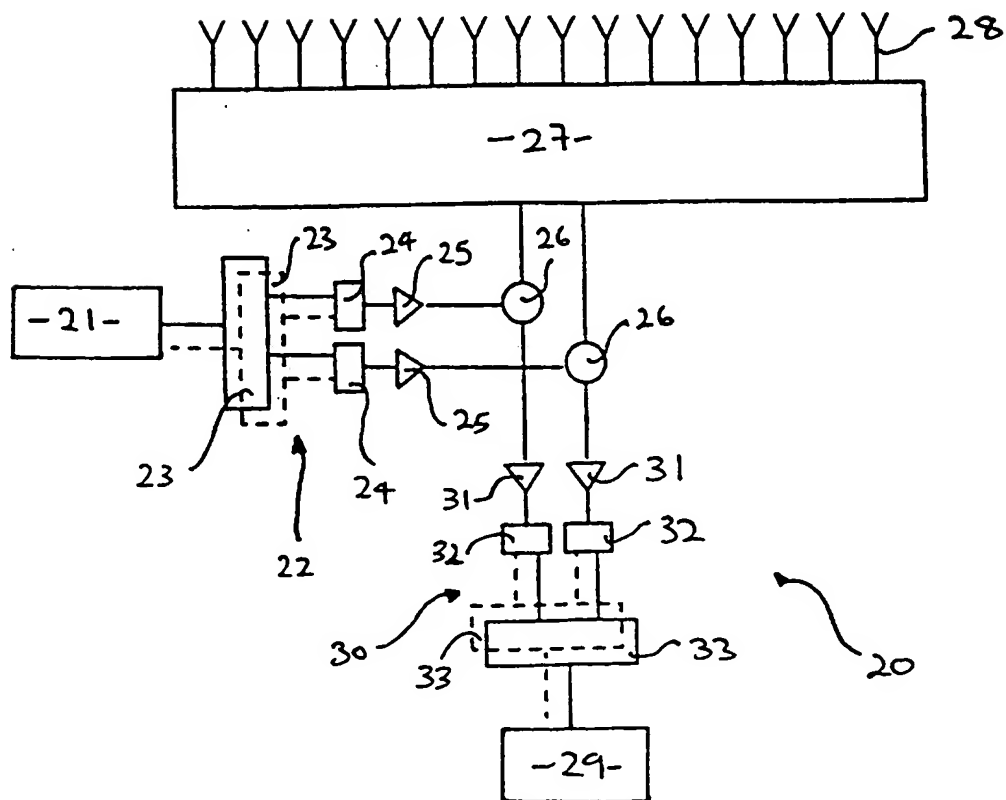


Fig. 2.

SIGNAL PROCESSOR SYSTEM

This invention relates to a signal processor system, for processing beams comprising sets of sub-signals of different phases.

A signal processor system for multiple beam antenna is proposed. A purpose of this
5 system is to eliminate and simplify active transmit and receive circuitry in multiple beam systems by introducing phase shifters and advanced beamforming networks.

Antenna systems for radars and satellite communication systems frequently need to generate multiple beams simultaneously. Conventional technology enables an antenna
10 to generate simultaneous sets of beams without losses (i.e. with ohmic loss only) provided that the set of beams is orthogonal. Orthogonality is not generally acceptable in terms of system performance because adjacent beams must either cross over at very low levels or have high sidelobes. This is generally overcome by using duplication of hardware in the transmit and receive system. This solution can represent a substantial
15 cost penalty.

If the antenna system requires multiple beams which are required sequentially, these are normally achieved by a switching arrangement. Applications include re-configurable satellite communications antennas, SSR with limited lookback capability, tracking over
20 a small field of view etc. Often this results in a large number of expensive and lossy switches or switched line phase shifters.

If a set of beams can be achieved by the combination of a set of orthogonal radiating beams using a minimum amount of active equipment (switches, receivers, phase shifters etc.) then a more cost effective approach to the antenna system is possible. Potential
5 reductions in system cost are significant.

This signal processor system offers advantages in the following areas:

In surveillance radar, range performance could be extended at the expense of height
10 cover by switching a cosec² beam shape to a pencil beam for an extended range mode. A set of cosec² beam shapes for different ranges could be used in sequence during the receive phase of each pulse, these would achieve higher gain at high elevation angles for short range which would release greater amounts of energy for long range detection.

15 In step tracking systems applying angular estimation or beam repointing using a step track technique, the mechanical beam deflection could be replaced by a simpler electrical system. A similar capability could be used to counteract multipath fading by applying angular diversity to communication links;

20 In beam broadening and zoom antenna systems, a broadened antenna beam width enables a surveillance radar to quickly search a solid angle at the expense of reduced range. This can be achieved by introducing a parabolic phase error at the antenna aperture in a system which incorporates phase shifters, this mode could also be introduced to less sophisticated systems. Zoom antennas have been the focus of

attention for spacecraft with elliptical orbits for some time, allowing the beam shape to be adapted to the coverage region as the range of the spacecraft changes. Systems have been proposed where this is achieved by phase control of a circularly symmetrical array, this proposed system allows more complex variations of antenna excitation;

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For re-configurable antenna, a number of independent radiation patterns can be generated, differing only in the phase shifter settings of a beam-transformer. This lends itself to the re-configuration of satellite antenna systems whilst in orbit, and

10 In multi-matrix antenna systems, this system adds a new degree of freedom to traditional multiple matrix beamforming networks, enabling the design of more sophisticated performance without significant changes to the overall system architecture. In the Inmarsat 3 L-band transmit payload the multiple beam solution was constrained by the available concepts of the output-networks used in the system. Removing this constraint
15 will obviate the need for the rotating feeds, motors and extended cable lengths.

Existing active matrix feed systems for antennae fall into either of two categories, a multi-matrix feed system or a multi-mode feed system.

20 In a multi-matrix system a set of beams which are not orthogonal to one another are generated, in general, using an array of radiating elements, a number of power dividers having an equal number of input ports as output ports and one at least output port corresponding to each radiating element, one amplifier for each power divider input, one beam combiner for each amplifier and one beamformer for each beam, each beamformer

having as many outputs as there are amplifiers.

Generally a multi-mode system generates a set of beams which are orthogonal to one another. The system comprises an array of radiating elements, a single power divider
5 with an equal number of outputs as radiating elements and as many inputs as beams. The inputs to the power divider can be driven either by a set of amplifiers, one amplifier for each input, or by a multi-matrix system as described above.

It is possible to construct a hybrid multi-matrix system which generates non-orthogonal
10 beams using an array of radiating elements, a single power divider with an equal number of outputs as radiating elements and as many inputs as beams, one amplifier for each power divider input, one beam combiner for each amplifier a beamformer for each beam and having as many outputs as there are amplifiers.

15 The prior art allows the formation of orthogonal beams with up to the same number of formed beams as there are feeds. The prior art also allows the formation of non-orthogonal beams using a greater or equal number of amplifiers than there are feeds.

It is an object of the present invention to process beams comprising sets of sub-signals
20 of different phases to generate beams, which are not necessarily orthogonal, and to derive received signals from such beams.

According to a first aspect of the present invention there is provided a signal processor system, for transmitting beams comprising sets of sub-signals of different phases,

comprising a feed having a transmitter to supply transmission signals, a signal manipulator operably connected between the transmitter and a beam-transformer which is further operably connected to an antenna, and the signal manipulator is arranged to divide the transmission signals into sets of sub-signals and to manipulate the phases of the sub-signals in each set, and the beam-transformer is arranged to combine the sub-signals of each set and to cause the antenna to transmit the transmission beams.

According to a second aspect of the present invention, there is provided a signal processor system, for processing beams comprising sets of sub-signals of different phases to be received by an antenna, comprising a feed having a receiver to accept received transmission signals, a signal manipulator operably connected between the receiver and a beam-transformer which is further operably connected to receive the beams received by an antenna, and the beam-transformer is arranged to divide each received beam into sets of sub-signals and the signal manipulator is arranged to manipulate the phases for the sub-signals in each set and to combine the sub-signals of each set to form received signals.

Preferably the transmitter and receiver may be operably connected to the signal manipulator with at least one diplexer.

20

The transmitter and the receiver may share a common signal manipulator and a common beam-transformer, or the transmitter and receiver may each have a separate signal manipulator and may share a common beam-transformer.

At least a pair of the transmission beams may be non-orthogonal or at least a pair of the transmission beams may be orthogonal.

5 According to a further aspect of the present invention there is provided a signal processing method, comprising dividing transmission signals into sets of sub-signals and independently altering the phase of the sub-signals in each set using a signal manipulator, and combining the sub-signals of different sets, using a beam-transformer, to form transmission beams and using each beam to excite an aperture of an antenna.

10 According to another aspect of the present invention there is provided a signal processing method, comprising dividing received beams into sets of sub-signals, using a beam-transformer, and independently altering the phase of the sub-signal in each set using a signal manipulator and forming received signals by combining the sub-signals of different sets.

15

Preferably a transmitter unit may be operably connected to the signal manipulator arrangement through a diplexer arrangement. A receiver unit may also be operably connected to the signal manipulator arrangement through a diplexer arrangement.

20 The invention is further described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 illustrates a first embodiment of the present invention for generating sequential transmission beams and for deriving received signals sequentially, and

Figure 2 illustrates a second embodiment of the present invention for generating simultaneous transmission beams and for deriving received signals simultaneously.

5 In Figure 1, a signal processing system 10, for the sequential generation of a pair of transmission beams and for the sequential derivation of received signals form a pair of beams, is constructed from a transmitter 11 and a receiver 12 operably inter-connected with a diplexer 13, to allow the simultaneous transmission or reception of signals using a common antenna.

10 Diplexer 13 is also operably connected to a signal manipulator 14 comprising a hybrid coupler 15 operably connected to each of a pair of parallel variable switched phase shifters 16, one phase shifter corresponding to each input of a beam transformer 17. The output of each phase shifters 16 is fed to the inputs of a beam transformer 17 which is

15 further operably connected to an antenna 18.

The pair of beams, which are not necessarily orthogonal are generated in the following manner. A transmission signal from the transmitter 11 is routed through the diplexer 13 and divided into two equal sub-signals by the hybrid coupler 15. The phase of the two

20 sub-signals are independently adjusted by phase shifters 16 and fed to the inputs of the beam-transformer 17 as a first set of sub-signals.

The beam-transformer 17 recombines this set of sub-signals to form the aperture excitations required for a first beam. Resetting each phase shifter 16 to an alternative

phase setting causes the recombination of a second set of sub-signals and results in the formation of the aperture excitations required for a second beam.

5 A pair of beams, which are not necessarily orthogonal are processed in the following manner to derive received signals at the receiver unit 12. A pair of beams are received by antenna 18 and fed to beam-transformer 17 to convert the beams into sets of sub-signals. Each sub-signal of a first set are passed to its respective phase-shifter 16 which independently adjusts the phase of its sub-signal. The set of phase adjusted sub-signals are then recombined by the hybrid coupler 15 to form a received signal which is passed
10 through the diplexer 13 to the receiver 12.

Resetting the two phase shifters 16 to an alternative phase setting causes the recombination at the hybrid coupler 15 of a second set of sub-signals which form a second received signal that is passed through the diplexer 13 to the receiver 12.

15

In Figure 2, a signal processor 20, for the simultaneous generation of a pair of beams and the simultaneous derivation of a pair of received signals, is constructed from a transmitter 21 operably connected to a signal manipulator 22, which comprises a pair of parallel signal dividers 23. Each signal divider 23 is capable of controlling the
20 phase of the sub-signals passed through it, and is operably connected to a signal combiner 24 which is further operably connected in series with an amplifier 25.

The output of each amplifier 25 is operably connected to a diplexer 26 which allows the simultaneous transmission or reception of signals using a common antenna. Also

operably connected to the diplexers 26 are a receiver unit through its associated circuitry which will be described below with reference to the derivation of received signals. Each diplexers 26 is also operably connected to a common beam-transformer 27 which is in turn connected to an antenna 28.

5

A pair of beams, which are not necessarily orthogonal are generated in the following manner. A transmission signal from transmitter 21 is divided into a pair of equal sub-signals by each signal divider 23 and the phases of the sub-signals are independently adjusted at the output of each signal divider 23 by its respective phase setting. A sub-
10 signal from each signal divider 23 form alternative sets of sub-signals which are fed to a signal combiner 24. Each signal combiner 24 combines the sub-signals of their respective set to provide a combined signal output of that set which is routed to the respective amplifier 25 associated with each signal combiner 24. This results in all of the amplifiers 25 operating at the same power level independently of the power level of
15 each combined signal.

The output of each amplifier is passed to its respective diplexer 26, the output of which is in turn fed to the respective input of the common beam-transformer 27.

20 In this embodiment, the phase relationships established at each signal divider 23 attached to, for instance, a first beam input of the beam-transformer 27 recombine to form the desired feed excitation for a first beam and the phases relationships established at each signal divider 23 attached to, for instance, a second beam input recombine to result in the correct feed excitation for a second beam.

As mentioned above, a receiver 29 and its associated circuitry is operably connected to the diplexers 26. The diplexers 26 are operably connected to a signal manipulator 30 which comprises a parallel pair of low noise amplifiers 31, the input of each amplifier 31 connected to the output of one diplexer 26. The input of a signal divider 32 is
5 operably connected to each amplifier 31 and each of a pair of outputs are operably connected to each of a pair of signal combiners 33. Each signal combiner 33 is capable of controlling the phase of a set of sub-signals passed through it. Each signal combiner 33 is operably connected to the receiver 29.

10 A pair of beams, which are not necessarily orthogonal, are processed in the following manner to derive received signals at the receiver unit 29. A pair of beams are received by antenna 28 and fed to beam-transformer 27 which converts the beams into signals. The signals are routed via the diplexers 26 to their respective amplifiers 31. Each signal divider 32 divides the signals from its respective amplifier 31 into sub-signals and one
15 of each of sub-signal is fed to each signal combiner 33. The phases of each sub-signal are independently adjusted at the input of each signal combiner 33 by its respective phase setting and a set of sub-signals combined by each signal combiner 33 to form received signals at the receiver unit 29.

20 Although each embodiment of the invention has been described with reference to a pair of formed beams or a pair of received signals, the systems can be extended to operate with a greater number of beams by increasing the number of phase shifters 16 and the number of outputs of the hybrid coupler 15 in the first embodiment or signal combiners 33 in the second embodiment to equal the number of beams to be formed, each shifter

16 or combiner 33 having an alternative phase setting for each formed beam or received signal.

For example, for the first embodiment, extension from a two beam system having two
5 variable switched phase shifters 16, each phase shifter 16 having two alternative phase
settings, is achieved by having a system with N beams, N phase shifters, each phase
shifter having N alternative phase settings.

For a further example, in the second embodiment, extension from a two beam system
10 formed from two signal dividers 23 each having their own phase setting on each output,
it is possible to construct a system having N beams, formed by N signals dividers, each
having their own phase setting on each output.

15

20

Claims

1. A signal processor system, for transmitting beams comprising sets of sub-signals of different phases, comprising a feed having a transmitter to supply
5 transmission signals, a signal manipulator operably connected between the transmitter and a beam-transformer which is further operably connected to an antenna, and the signal manipulator is arranged to divide the transmission signals into the sets of sub-signals and to manipulate the phases of the sub-signals in each set, and the beam-transformer is arranged to combine the sub-signals of
10 each set and to cause the antenna to transmit the transmission beams.
2. A signal processor system, for processing beams comprising sets of sub-signals of different phases to be received by an antenna, comprising a feed having a receiver to accept received transmission signals, a signal manipulator operably
15 connected between the receiver and a beam-transformer which is further operably connected to receive the beams received by an antenna, and the beam-transformer is arranged to divide each received beam into sets of sub-signals and the signal manipulator is arranged to manipulate the phases for the sub-signals in each set and to combine the sub-signals of each set to form received signals.
20
3. A signal processor system, as claimed in Claims 1 and 2, wherein the transmitter and receiver are operably connected to the signal manipulator with at least one diplexer.

4. A signal processor system, as claimed in Claim 3, wherein the transmitter and the receiver share a common signal manipulator and a common beam-transformer.
5. A signal processor system, as claimed in Claim 3, wherein the transmitter and receiver each have a separate signal manipulator and share a common beam-transformer.
6. A signal processor system, as claimed in any preceeding claim, wherein at least a pair of the transmission beams are non-orthogonal.
7. A signal processor system, as claimed in any of Claims 1 to 5, wherein at least a pair of the transmission beams are orthogonal.
8. A signal processor system substantially as illustrated in and described with reference to the accompanying drawings.
9. A signal processing method, comprising dividing transmission signals into sets of sub-signals and independently altering the phase of the sub-signals in each set using a signal manipulator, and combining the sub-signals of different sets, using a beam-transformer, to form transmission beams and using each beam to excite an aperture of an antenna.
10. A signal processing method, comprising dividing received beams into sets of sub-signals, using a beam-transformer, and independently altering the phase of

the sub-signals in each set using a signal manipulator and forming received signals by combining the sub-signals of different sets.

11. A method substantially as illustrated in and described with reference to the
5 accompanying drawings.



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Claims searched: 1 to 11

Examiner: Peter Easterfield
Date of search: 3 January 1997

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

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Int Cl (Ed.6): H01Q 3/00, 3/26, 3/30, 3/34, 3/36, 3/38, 3/40

Other: Online: WPI, JAPIO, CLAIMS

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2034525 A (MARCONI) see fig 4	1,2,9 & 10 at least
X	GB 1454554 A (INTERNATIONAL STANDARD ELECTRIC) see fig 3	1,2,9 & 10 at least
X	EP 0568886 A1 (ALCATEL ITALIA) see fig 3	1,2,9 & 10 at least
X	EP 0215971 A1 (ALLIED CORP.) see fig 1	1,2,9 & 10 at least
X	US 5430452 A (DUBOIS et al) see fig 1	1,2,9 & 10 at least
X	US 5151706 A (ROEDERER et al) see figs 5, 7 & 8	1,2,9 & 10 at least
X	US 4814775 A (RAAB et al) see fig 7b	1,2,9 & 10 at least
X	US 4257050 A (PLOUSSIOS) see figs 2 & 3	1,2,9 & 10 at least
X	US 4246585 A (MAILLOUX) see fig 3	1,2,9 & 10 at least

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